

Georgia Institute of Technology
Office of Sponsored Program
OSP Amendment - Deliverable Schedule
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Doc ID #: 106629
Old Project Number:
P/S Project Number: 12966H4
Rev #: 1 Mod #: NCE
Current Revision Completion Date: 10-JAN-08

Doc ID #: 106629

Sponsor: THIRD WAVE SYSTEMS/MINNEAPOLIS, MN

Award Document: AGR

Contract #: AGR SIGNED 10/1/2007

Contract thru: GTRC

Project Director(s):

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Unit: MARC

Initiation Date: 31-AUG-2007

Termination Perf Date: 31-MAR-2008 (Performance)

Termination Rpts Date: 31-MAR-2008

Project Title: FREEFORM OPTICAL SYSTEMS FOR DEFENSE SYSTEM OPTICS- MACHINABILITY

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Note: Deliverables sorted on 'Due Date to Sponsor' column

Rev No (1)	Description of Deliver- able	Deliv Id No (2)	Period	Covered	Due Date to Sponsor (3)	Copies reqd	Date Mailed^	Sat^
*1	FINAL RE- PORT	1	31-AUG-20 07	31-MAR-20 08	31-MAR-20 08	1	26-MAR-20 08	N

Total Count:1

^ = Satisfied (Note: OSP considers a deliverable satisfied if Sat column is Y OR if there is a mailed date).

PLEASE NOTE:

- 1.An asterisk denotes this deliverable was changed or added by the mod.
- 2.The Deliverable Id No will remain associated with its originally assigned deliverable for the duration of the project.
Modifications to the project will no longer cause this number to be sequentially renumbered.
- 3.Blanks in the 'Due Date to Sponsor' indicate 'as appropriate' or 'as required'.
- 4.Blanks in 'Date Mailed' indicate that neither delivery nor notification of delivery has been accomplished through OSP/CSD.

Prepare reports in accordance with: Final Report due December 31, 2007 per Section 4

Please review the schedule for accuracy and contact the CO if changes are necessary.

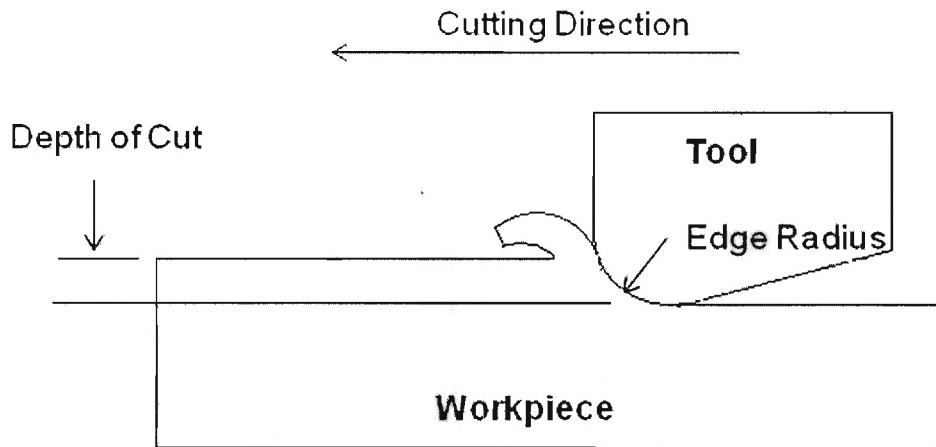


Figure 1. Definitions of edge radius and edge of cut in AdvantEdge 2D simulations

	3 μm Edge Rad				4.5 μm Edge Rad			
Depth of cut (μm)	0.5	1.0	1.5	2.0	0.75	1.5	2.25	3.0
Fraction of Edge Radius	1/6	1/3	1/2	2/3	1/6	1/3	1/2	2/3

Table 1. Depth of cut used in 2D simulations

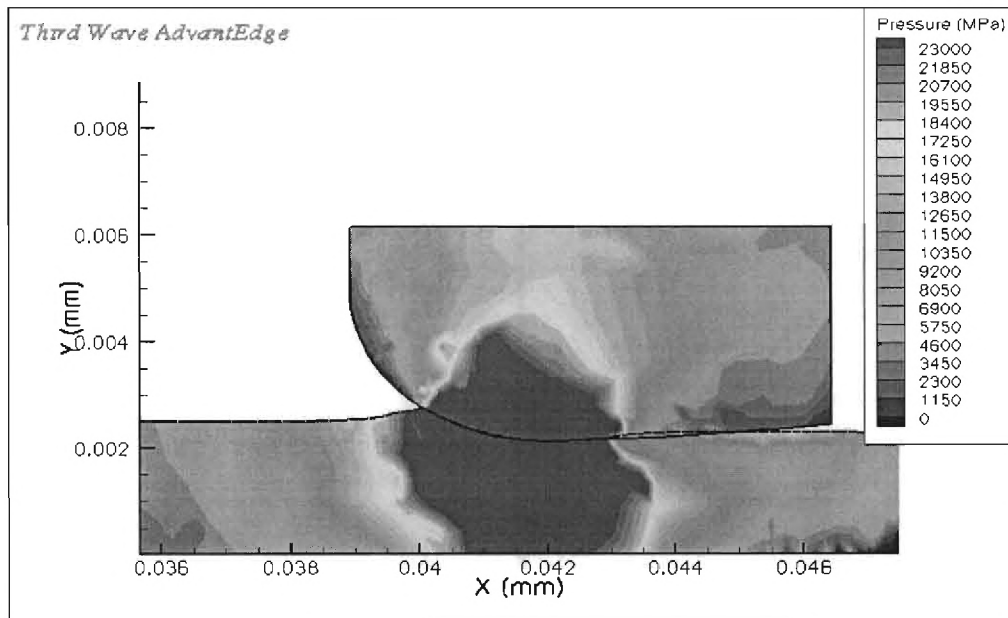


Figure 2. Pressure distribution for a 0.5 μm depth of cut with a tool with a 3 μm edge radius. This depth of cut is too shallow to produce a chip.

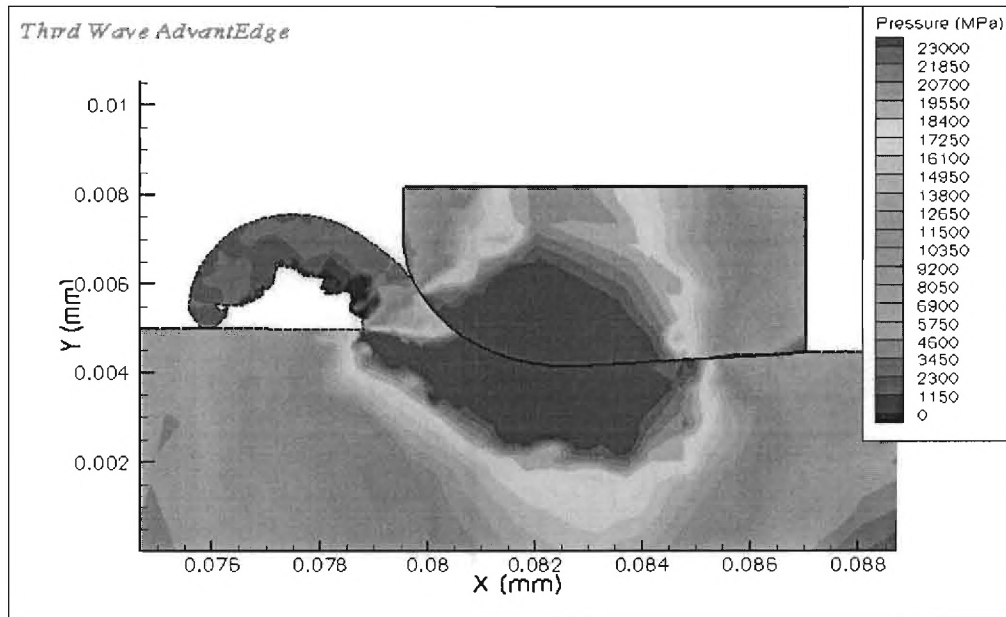


Figure 4. Pressure distribution for a 1.0 μm depth of cut with a tool with a 3 μm edge radius. This simulation indicates ductile mode chip formation.

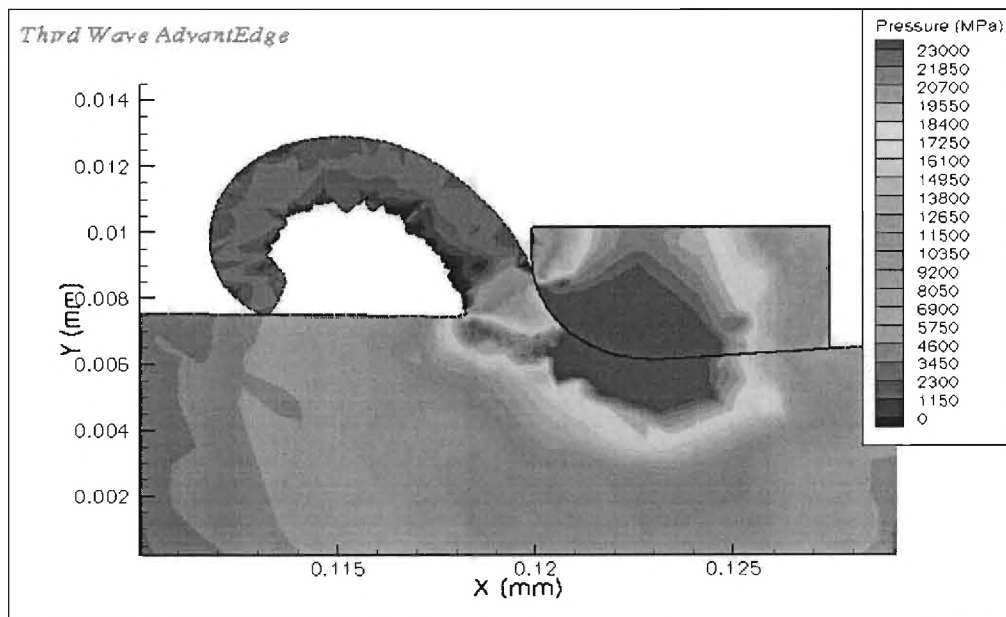


Figure 3. Pressure distribution for a 1.5 μm depth of cut with a tool with a 3 μm edge radius. This simulation indicates a chip formation, on the borderline of ductile mode regime.

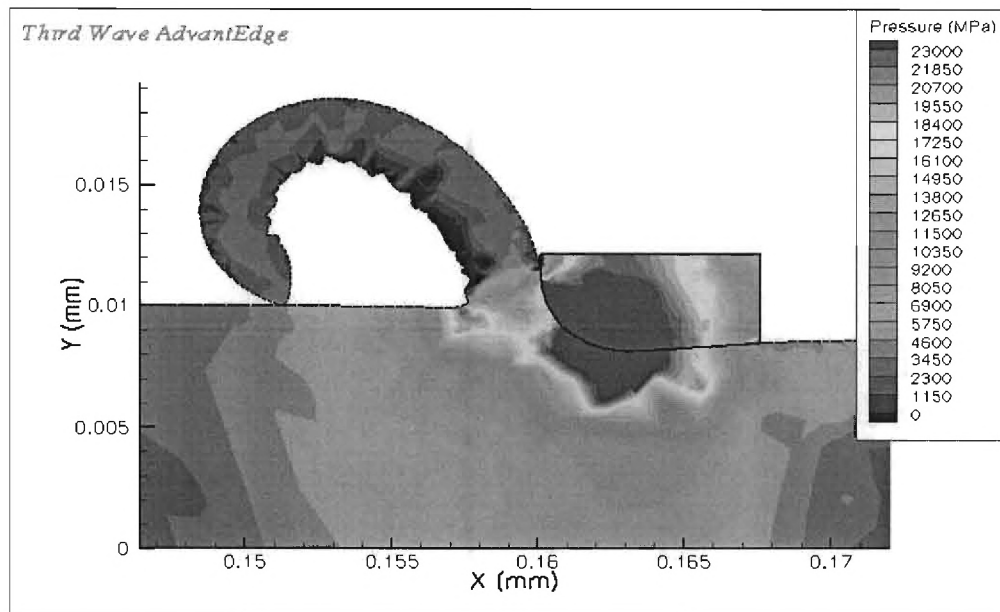


Figure 6. Pressure distribution for a 2.0 μm depth of cut with a tool with a 3 μm edge radius. This

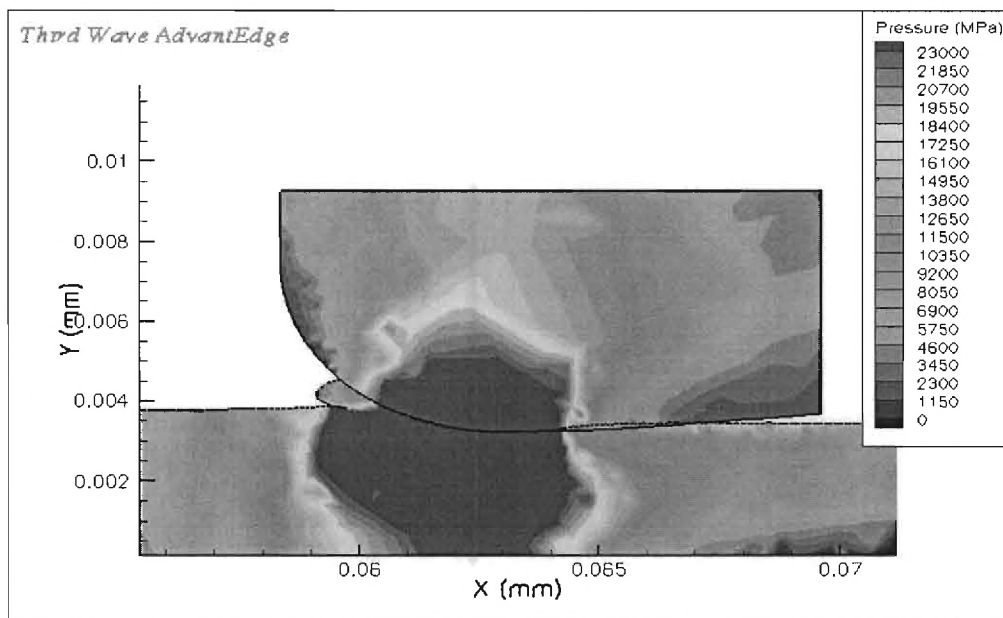


Figure 5. Pressure distribution for a 0.75 μm depth of cut with a tool with a 4.5 μm edge radius. This depth of cut produces a small chip and indicates ductile mode chip formation.

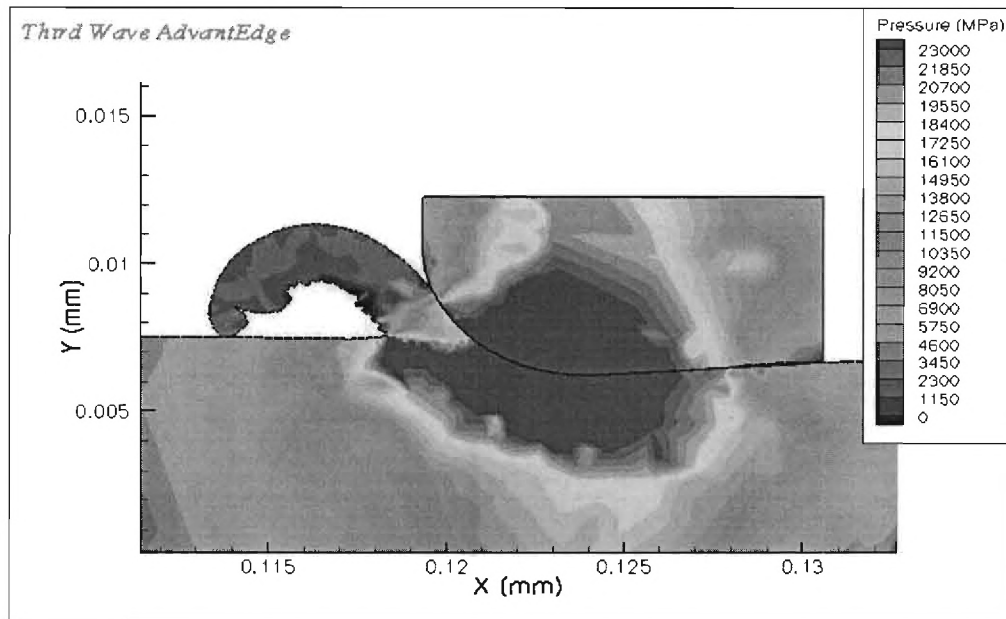


Figure 7. Pressure distribution for a 1.5 μm depth of cut with a tool with a 4.5 μm edge radius. This depth of cut indicates ductile mode chip formation.

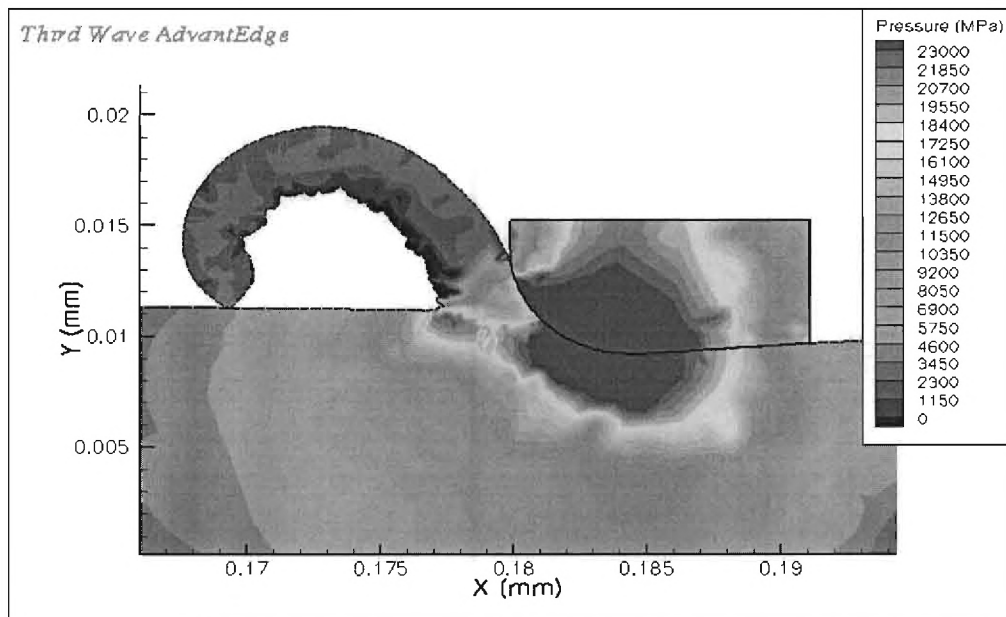


Figure 8. Pressure distribution for a 2.25 μm depth of cut with a tool with a 4.5 μm edge radius. This simulation indicates chip formation, on the borderline of the ductile mode regime.

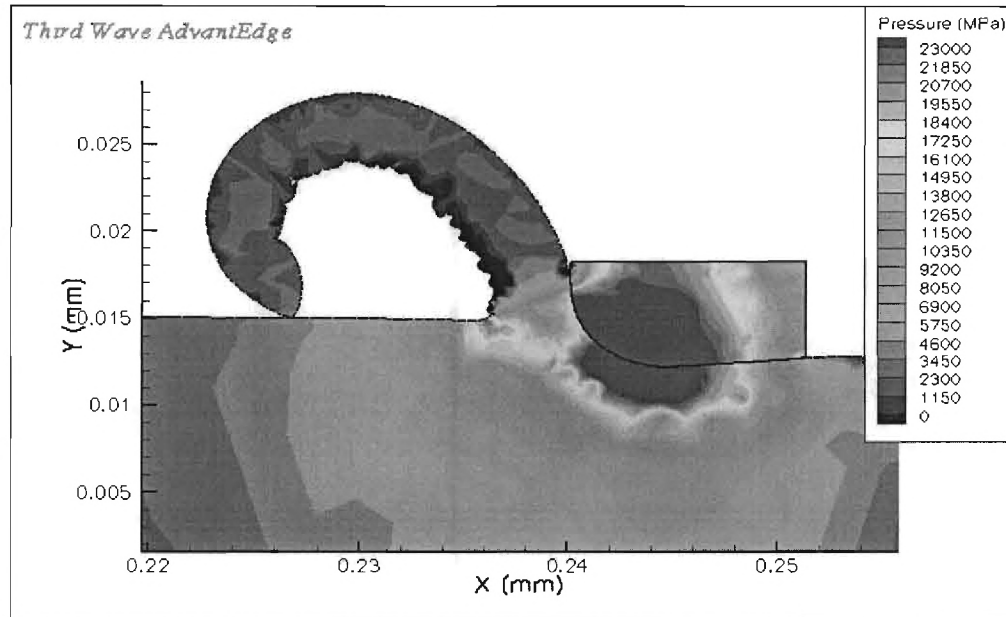


Figure 10. Pressure distribution for a $3.0\ \mu\text{m}$ depth of cut with a tool with a $4.5\ \mu\text{m}$ edge radius. This simulation indicates brittle mode chip formation.

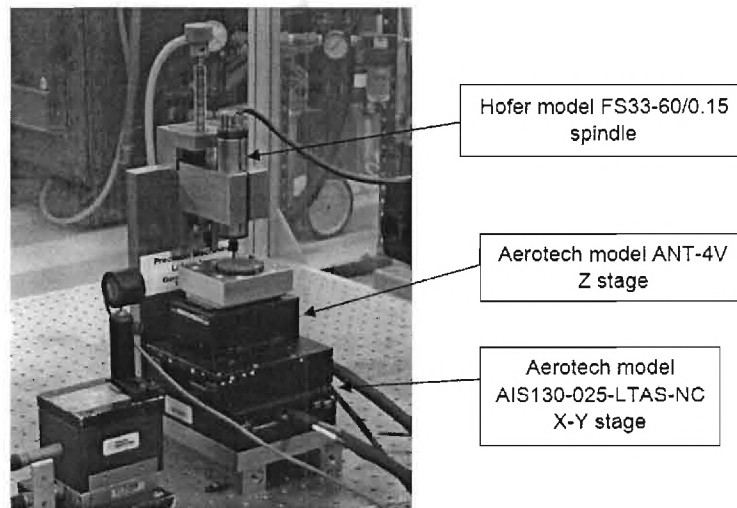


Figure 9: View of machine setup and component information

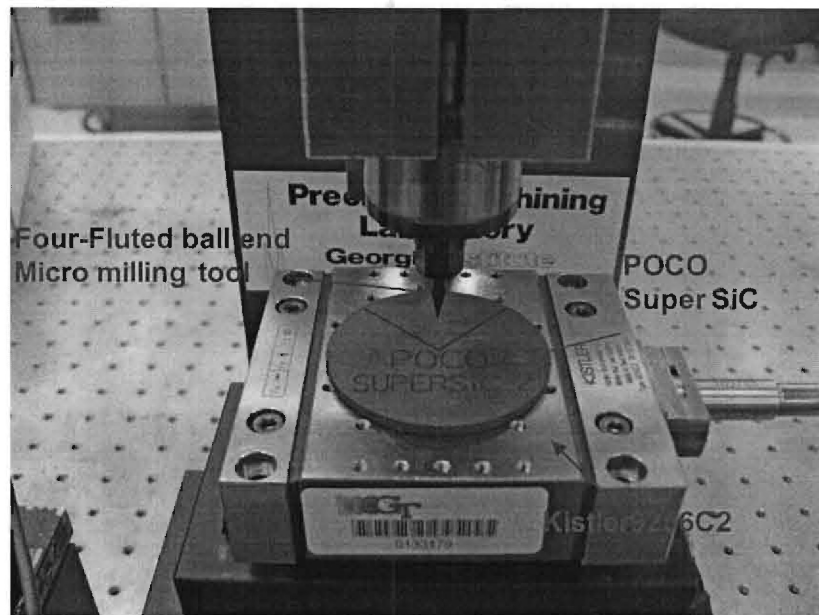


Figure 11. Experimental setup for DMM regime validation testing

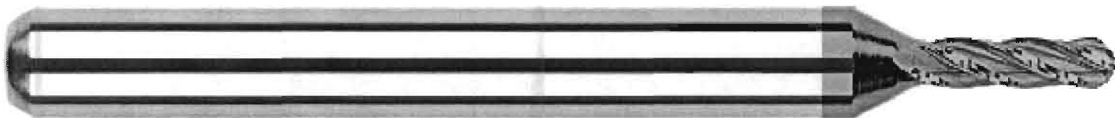


Figure 12. 0.25 mm diameter diamond coated end mill used in validation testing

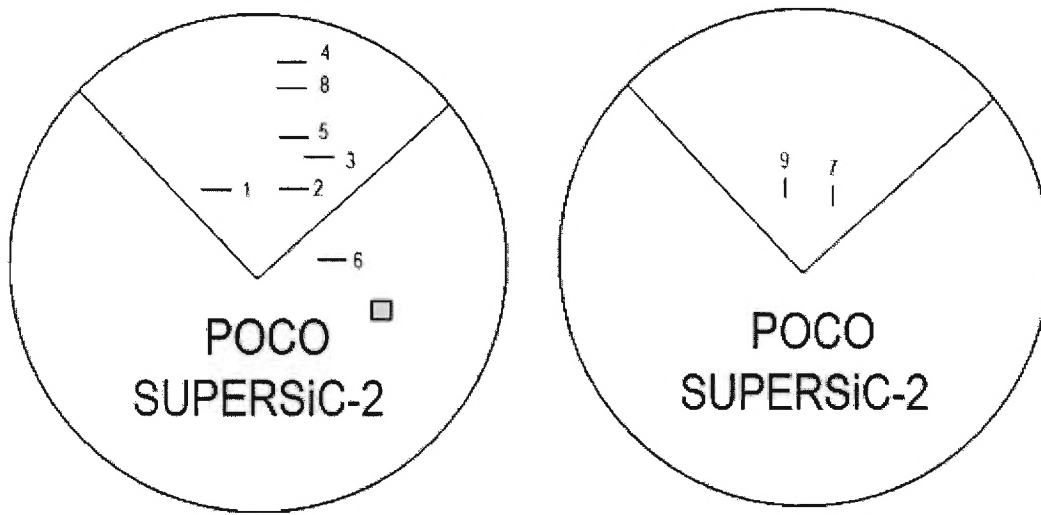


Figure 13. Distribution of test slots on the CVD-Sic Flat used in validation testing

Table 2: Summary of results on the brittle to ductile machining transition from the validation tests

Case	Feed (mm/min)	D.O.C (μm)	Spindle Speed (RPM)	Tool Diameter (μm)	Test Result
1	0.5	0.1	60000	250	Ductile
2	0.5	1.0	60000	250	Ductile
3	0.5	2.5	60000	250	Brittle
4	1.0	0.1	60000	250	Ductile
5	1.0	1.0	60000	250	Ductile
6	1.0	2.5	60000	250	Brittle
7	2.5	1.0	60000	250	Ductile
8	25	25	60000	250	Brittle
9	2.5	1.0	60000	500	Ductile

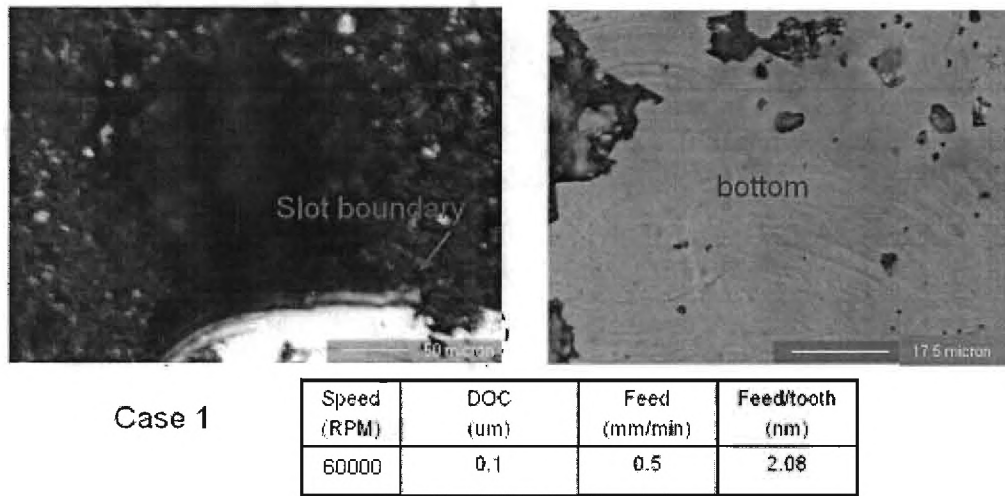


Figure 14. Photographs of the machined surface for Case 1. The edge of the slot showing predominately the as-received surface, left; and the final machined surface, right. The final machined surface shows substantially better finish after just one ductile machining pass.

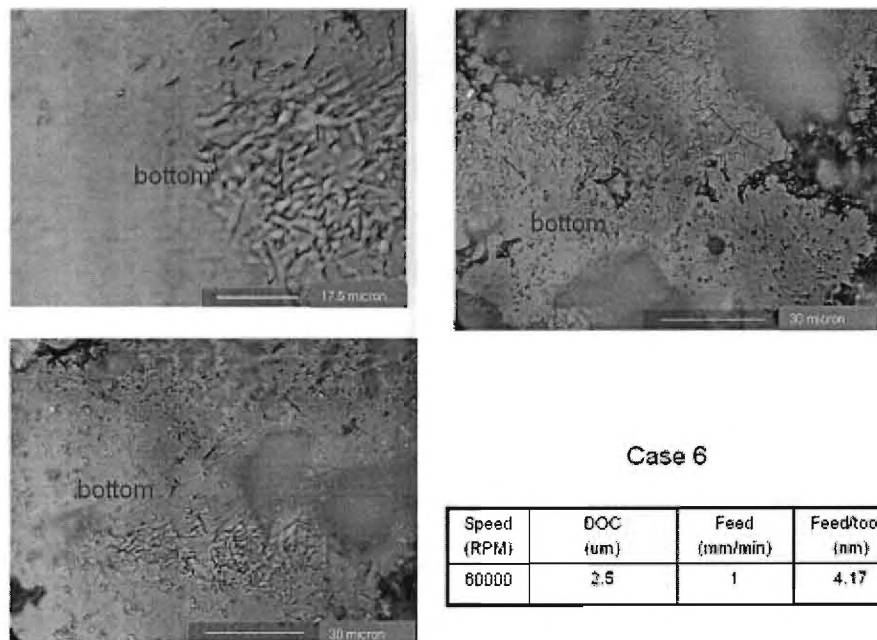


Figure 15. Photographs of the machined surface for Case 6 where brittle chip formation was observed.

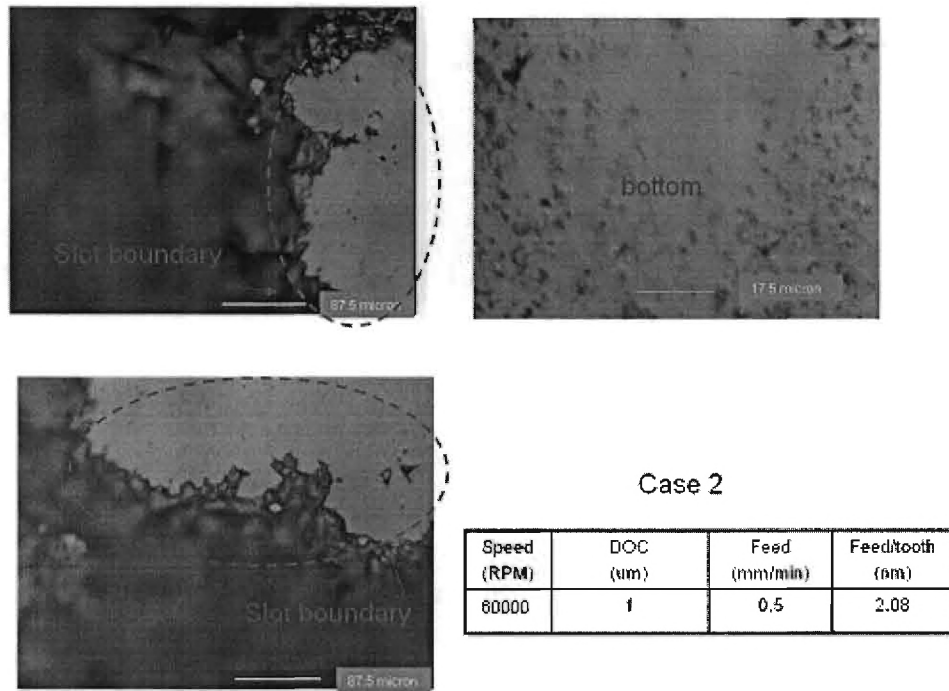
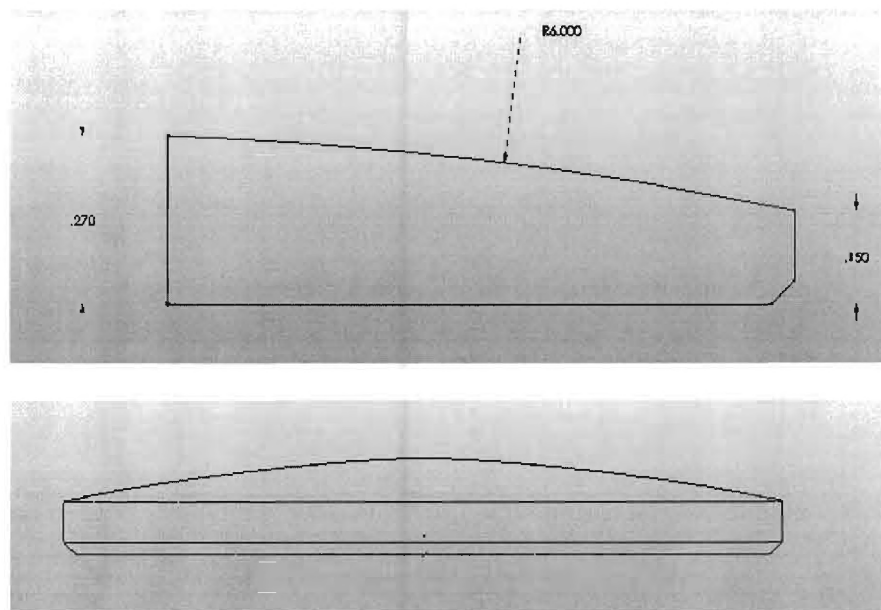
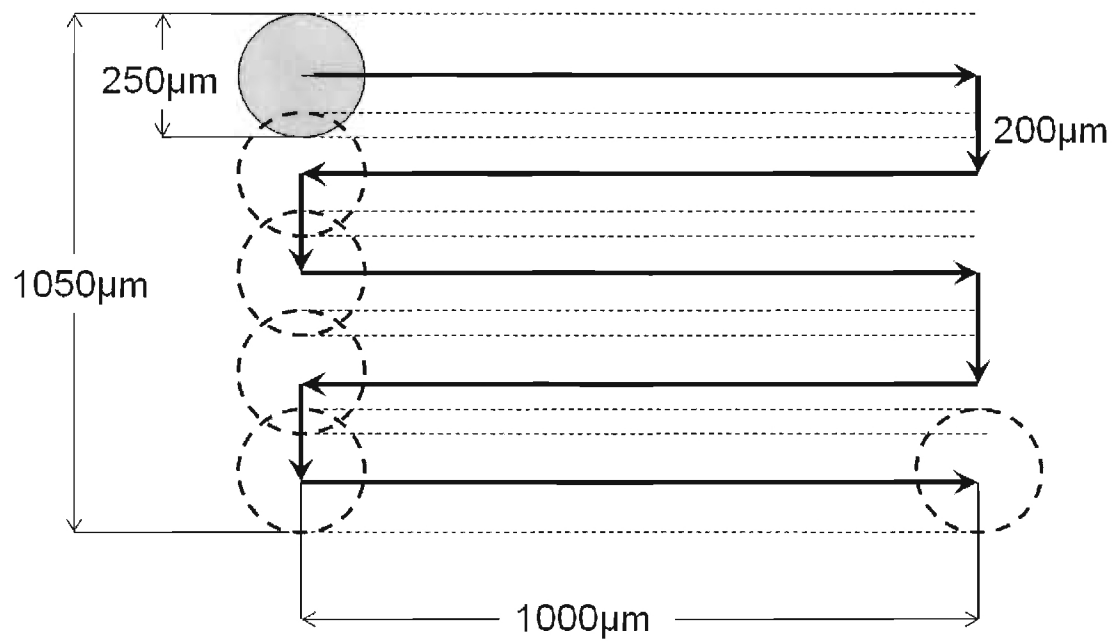


Figure 17. Photographs of the machined surface for Case 2

Figure 16. Convex Mirror from Poco Graphite used for Phase I feasibility demonstration





Speed (RPM)	DOC (μm)	Feed (mm/min)	Feed/tooth (nm)
6000	1	1	4.17

Figure 18. Tool path for side cutting and surface machining tests.

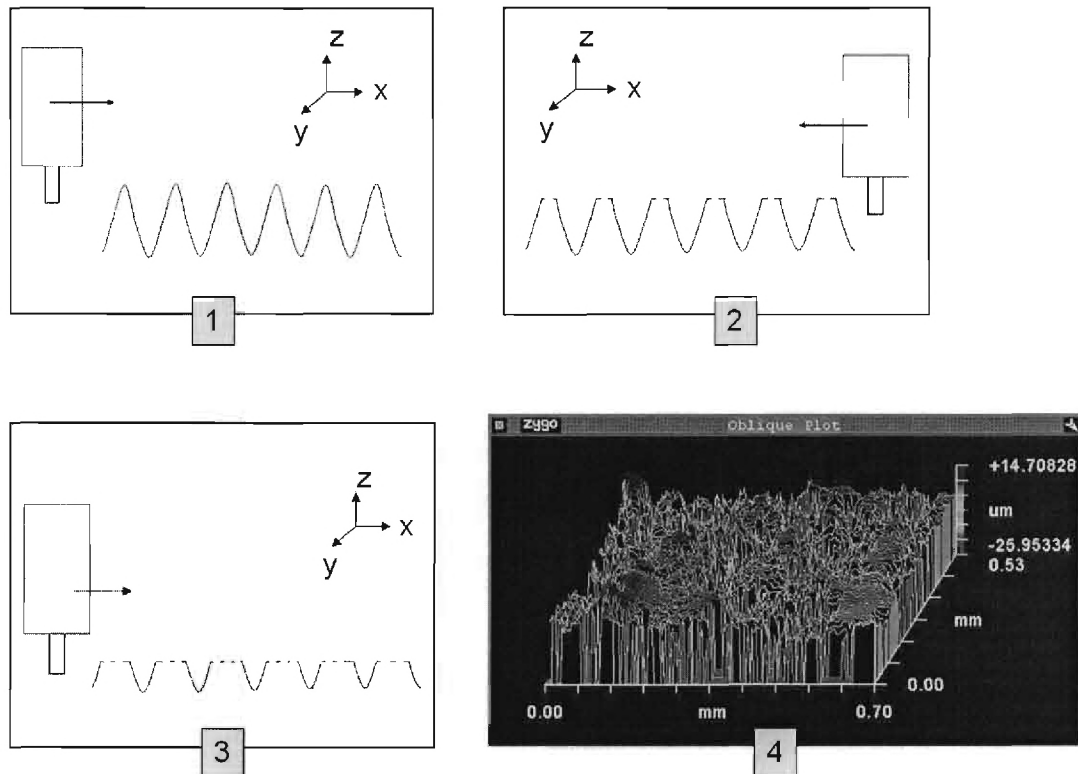


Figure 19. Multiple depth cutting plan to even out surface irregularities is shown. Schematics 1-3 depict the milling cutter traveling over the peaks in the surface finish, sequentially removing them in each pass. Picture 4 shows Zygo measurements of the initial surface with several peaks.

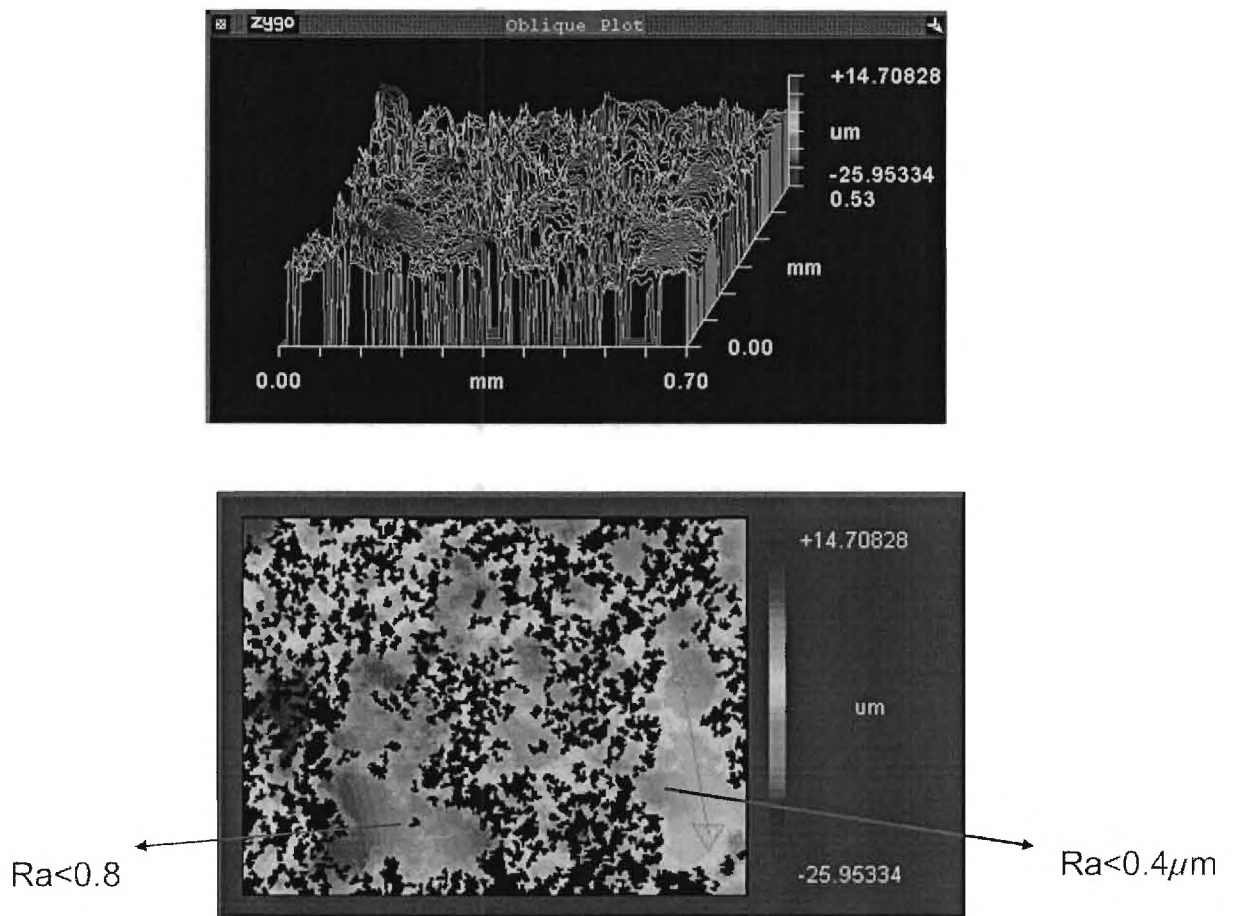


Figure 20. Machined surface finish for milling test. Not all of the initial surface was removed in this test, but for portions that were removed the machined surface finish was between 400nm-800nm R_a . This is an order of magnitude reduction in surface roughness.

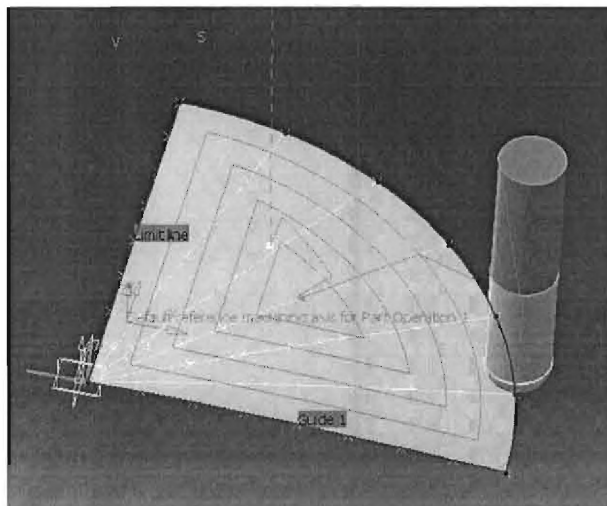
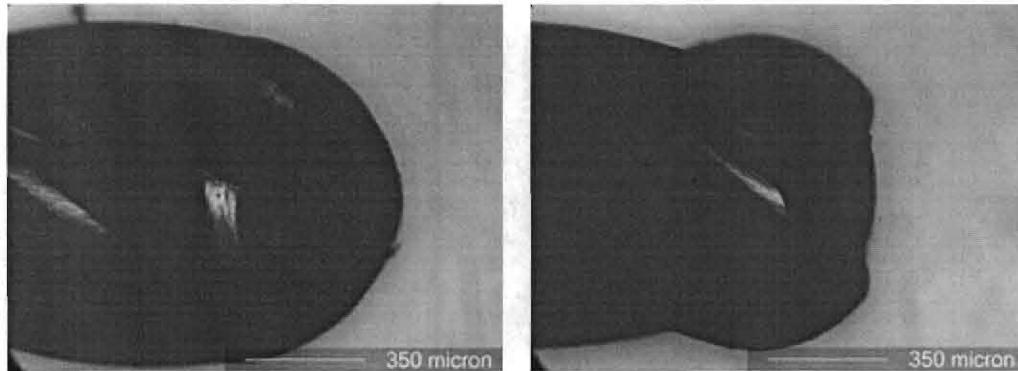


Figure 21. Toolpath from CATIA software of portion of quadrant. CMM data points shown along white lines.



New Tool

Worn Tool

Figure 22. New 2 mm diamond coated carbide tool on left. Tool after one spiral into center of quadrant on right, with significant wear.

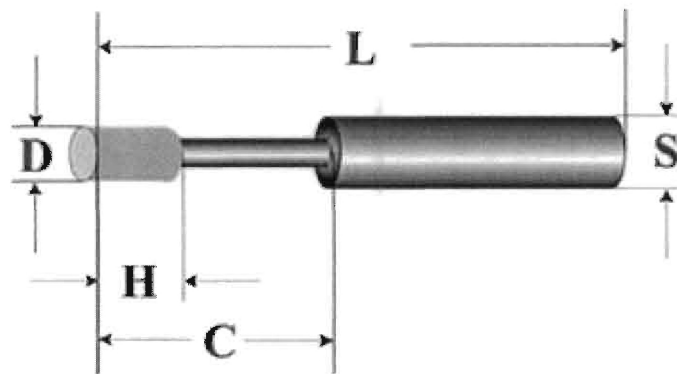


Figure 23. Mandrel used for reshaping the highly variable surface. Diameter of wheel was 3.125mm.

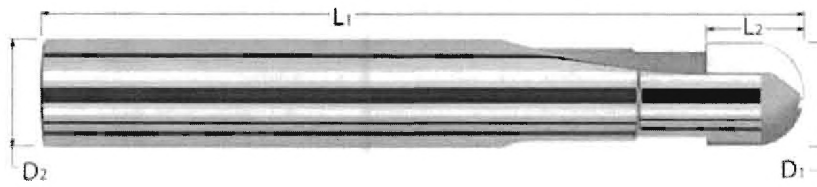


Figure 24. Single flute PCD braided ball mill used in final DMM demonstration.

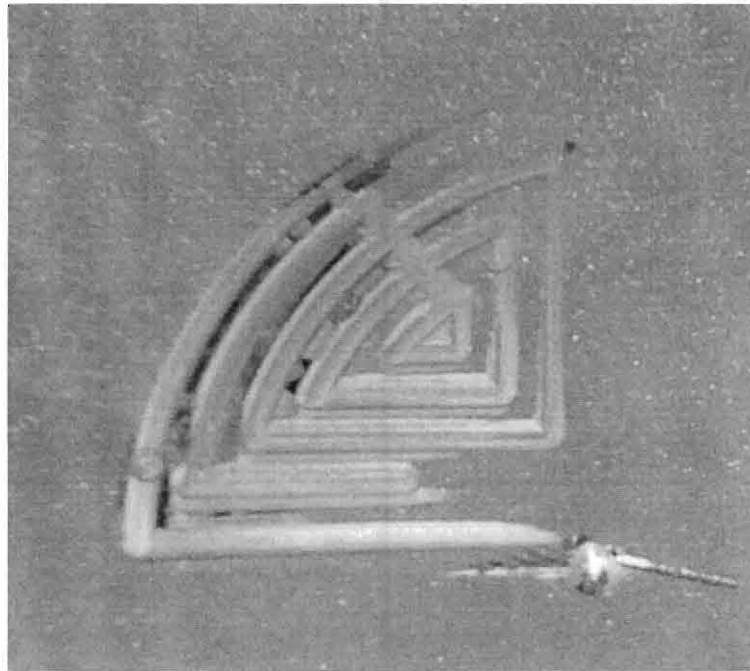


Figure 26. View of cut the location of the machined surface on the optic.

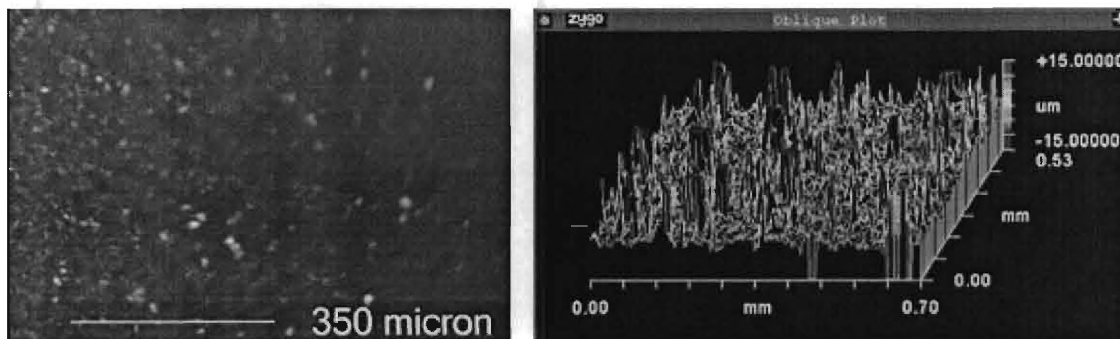


Figure 25. Magnified view of “As Received” surface and corresponding Zygo plot of 3D surface profile

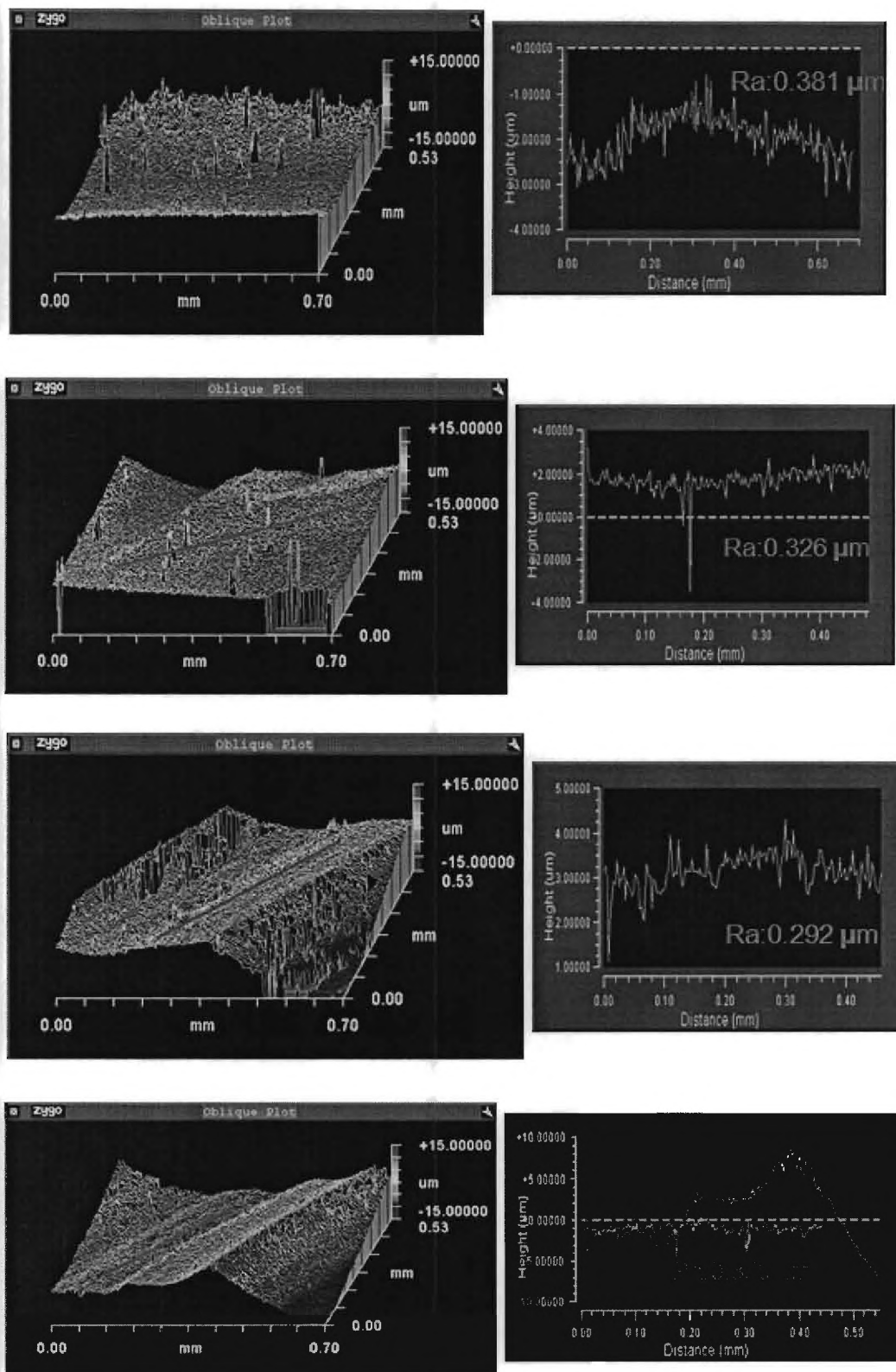


Figure 27. Zygo white-light interferometer plots and corresponding surface roughness for points along toolpath.

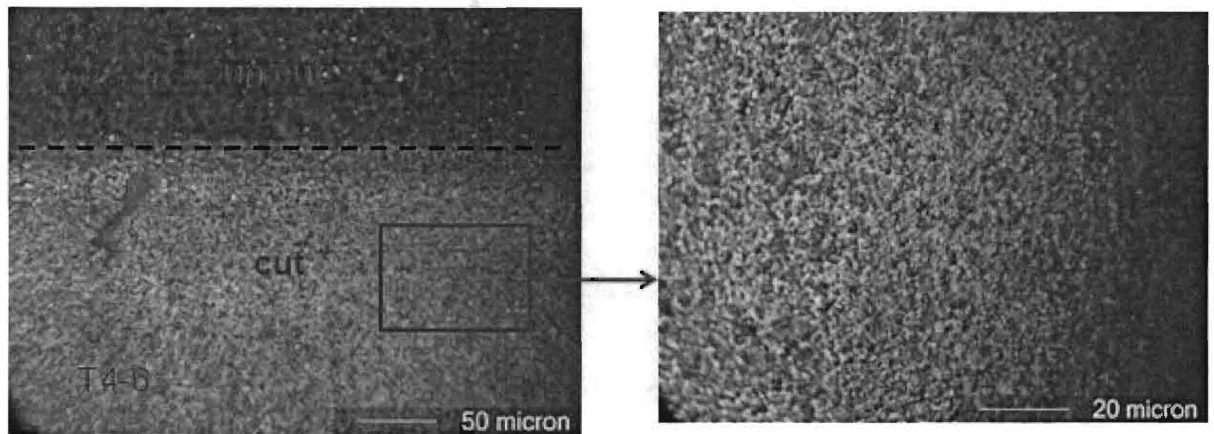
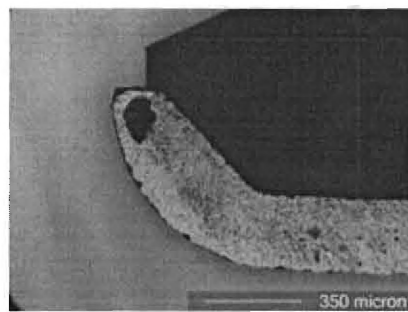
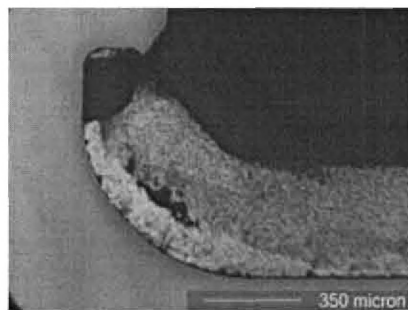


Figure 28. Magnified view of typical ductile mode machined surface, with uncut and cut region clearly distinguishable, left; and magnified DMM surface, right.



New PCD Diamond Tool



Used PCD Diamond Tool

Figure 29. Single Flute PCD brazed insert before and after five 1.0 μm ductile mode passes.

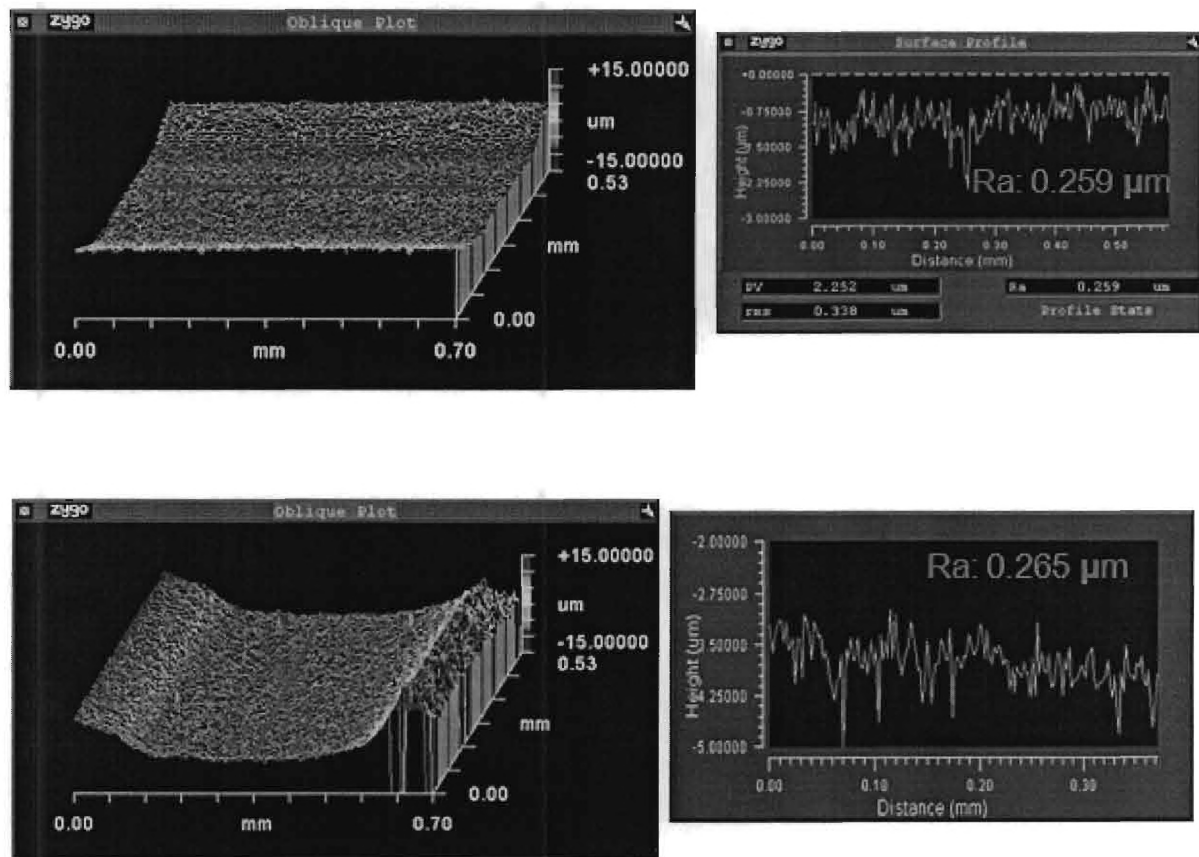


Figure 30: Zygo 3D surface profiles and measured R_a values for surfaces machined with 0.5 μm depth of cut and 5 nm/tooth feed.